

INDOOR AIR

Volume

2

Radon, Passive Smoking, Particulates and Housing Epidemiology

Editors

BIRGITTA BERGLUND

Department of Psychology, University of Stockholm

THOMAS LINDVALL

Karolinska Institute and the
National Institute of Environmental Medicine

JAN SUNDELL

National Board of Occupational Safety and Health

Swedish Council for Building Research
Stockholm, Sweden 1984

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA. 22161

2023379686

Proceedings of the 3rd International Conference on Indoor Air Quality and Climate

**held in Stockholm
August 20-24, 1984**

***Under the High Patronage of
His Majesty King Carl XVI Gustaf***

**Organized by
The Karolinska Institute and
The National Institute of Environmental Medicine
with the cosponsorship of
The World Health Organization**

Sponsored by
Commission of the European Communities
Swedish Ministry of Health and Social Affairs
U S Environmental Protection Agency
Swedish Council for Building Research
Swedish Work Environment Fund
National Institute of Radiation Protection (Sweden)
Representatives of European Heating and Ventilating Associations
American Society of Heating, Refrigerating and Air-Conditioning Engineers
Electric Power Research Institute (USA)
Gas Research Institute (USA)
Ruhrgas AG (FRG)
Kawasaki Ltd (Japan)
Drägerwerk AG (FRG)
Fålt AB (Sweden)
Bahco AB (Sweden)
Brüel & Kjær (Denmark)

2023379687

2023379688

INDOOR AIR

Volume 2

Radon, Passive Smoking, Particulates
and Housing Epidemiology

The 3rd International Conference on Indoor Air Quality and Climate

Organizing committee

Thomas Lindvall, M.D., Professor (President)
Karolinska Institute and National Institute of Environmental Medicine,
Stockholm, Sweden

Birgitta Berglund, Ph.D., Professor
Department of Psychology, University of Stockholm and Swedish Council
for Research in the Humanities and Social Sciences, Stockholm, Sweden

Jan Sundell, M.Sc.
National Board of Occupational Safety and Health, Stockholm, Sweden

Overseas coordinators

Professor Kazuo Maeda
Department of Epidemiology, University of Tokyo, School of Health Sciences,
Tokyo, Japan

Dr Demetrios Moschandreas
IIT Research Institute, Chicago, Illinois, USA

Professor Bernd Seifert
Institute of Water, Soil and Air Hygiene, Berlin, Federal Republic of
Germany

Dr Peter Warren
Building Research Establishment, Watford, England

Advisory committee

Dr Ib Andersen
Danish National Institute of Occupational Health, Denmark

Dr David R. Berg
U.S. Environmental Protection Agency, Washington DC, USA

Dr Ulf Berglund
Royal Institute of Technology and National Institute of Environmental
Medicine, Sweden

Dr Irwin Billick
Gas Research Institute, USA

Professor Trygg Engen
Department of Psychology, Brown University, USA

Professor Povl Ole Fanger
Laboratory of Heating & Air Conditioning, Technical University of
Denmark, Denmark

Professor Benjamin Ferris Jr
School of Public Health, Harvard University, USA

Professor Lars Friberg
Karolinska Institute and National Institute of Environmental Medicine,
Sweden

2023379689

Professor Gideon Gerhardsen
Swedish Employers Confederation, Sweden

Dr Anna Hambræus
Institute of Clinical Bacteriology, University of Uppsala, Sweden

Dr Helmut Knöpperl
Joint Research Centre, Commission of the European Communities, Italy

Dr H W de Koning
Division of Environmental Health, World Health Organization,
Switzerland

Professor Michael D Lebowitz
Health Science Center, University of Arizona, USA

Dr Anthony Nero
Lawrence Berkeley Laboratory, University of California, USA

Professor Jan Stohr
School of Medicine, Yale University, USA

Dr Ralph M Perhac
Electric Power Research Institute, USA

Professor Eystein Rødahl
Norwegian Institute of Technology, University of Trondheim, Norway

Dr John D Spengler
School of Public Health, Harvard University, USA

Dr Michael Suess
World Health Organization, Denmark

Professor James Woods Jr
Engineering Research Institute, Iowa State University, USA

2023379690

CONTENTS

	Page
RADON IN DWELLINGS: EXPOSURE AND RISK ANALYSIS	13
Nazaroff, W U Nero, A V	Transport of radon from soil into residences 15
Jonassen, N McLaughlin, J P	Airborne radon daughters, behavior and removal 21
Edling, C Wingren, G Axelsson, O	Radon daughter exposure in dwellings and lung cancer 29
RADON: EXPOSURES AND RISKS	35
Svedjemark, G A Mjones, L	Exposure to the Swedish population to radon daughters 37
Fenyves, E J Kinslow, R H	Indoor radon concentrations in public buildings 43
Put, L W de Meijer, R J	Survey of radon concentrations in Dutch dwellings 49
Papastefanou, C Manolopoulou, M Savvides, El Charalambous, St	Exposure from radon and radon daughters in dwellings 55
Brown, L Green, B M R Miles, J C H Wrixon, A D	Radon exposure of the UK population 61
Burkart, W Wernli, C Brunner, H	Assessment of additional exposures and risks from airtightening of homes in an Alpine area with high radon emanation 67
Pershagen, G Damberg, L Falk, R	Exposure to radon in dwellings and lung cancer: A pilot study 73
Bergman, H Edling, C Axelsson, O	Indoor radon daughter concentrations and passive smoking 79
Wilson, C	Mapping the radon risk of our environment 85
Radford, E P St Clair Renard, K G	Application of studies of miners to radon problem in homes 93

2023379691

RADON: SOURCES AND MEASUREMENT

Downard, T R Geiger, E L Millard, J B	Field evaluation of Eberline's radon daughter working level monitor	99
Orwald, R A Alter, H W	Localization of indoor radon sources using integrating track etch detectors	105
Paripas, B Takacs, S Somogyi, Gy Nikl, I	Integral alpha and gamma radiation measurements in dwelling houses	113
Schmied, H	The sensitivity to humidity of radon monitoring instruments	119
Gustafsson, J Nilsson, I	Tracing of radon leakages	125
Hawthorne, A R Gemmage, R B Dudney, C S	Effect of local geology in indoor radon levels: A case study	137
Kothari, B K	Contribution of soil gas, potable water, and building material to radon in US homes	143
Keller, C Folkerts, K H	A study on indoor radon	149
Jönsson, G	Radon measurements in Sweden. Some results	155
Martell, E A	Aerosol properties of indoor radon decay products	161

FIBRES AND PARTICULATES IN THE INDOOR ENVIRONMENT

van Houdt, J J Boeleij, J S M	Mutagenic activity of indoor airborne particles compared to outdoors	169
Seifert, B Dreus, M Aurand, K	Indor heavy metal exposure of the population around a secondary lead smelter	177
Schneider, T	Man-made mineral fibers (MMF) and other fibers in the air and in settled dust	183
Sega, K Kalinic, M Sisovic, A	Indoor-outdoor relationships for respirable particles, total suspended particle matter and smoke concentrations in modern office buildings	189
McCarthy, S M Colome, S D Spengler, J D	Indoor and outdoor aerosols: A multivariate approach to source identification	195

2023379692

9

FIBRES AND PARTICULATES: CHARACTERIZATION AND RISKS 201

Weechler, C J Fong, K L	Characterization of organic species associated with indoor aerosol particles	203
Meckler, M	Analysis of low particulate size concentration levels in office environments	209
Janka, K Kulmala, V	Optical particle counter as a wide range, continuous monitor for particle concentrations	215
Rindel, A	Man-made-mineral fibres (MMMF) in indoor climate	221
Gunnarsson, M Bergström, B	Are man-made mineral fibres responsible for the development of bronchitis and atelectasis of the lung?	225
Tockman, M S Wheeler, P Prost, J K Ball Jr, W Levin, M Green, K	Pleural changes consistent with asbestos exposure found on screening radiographs are not predictive of lung cancer	229

EPIDEMIOLOGICAL STUDIES OF HEALTH DISORDERS RELATED TO HOUSING 235

Iversen, M Bach, E Lundqvist, G R	A prospective study of the health and comfort changes among tenants after retrofitting of their flats	237
Matsuki, H Yanagisawa, Y Osaka, F Kasuga, H Nishimura, H	Personal exposure to NO ₂ and its health effect with urinary hydroxyproline to creatinine ratio as biochemical indicator	243
Valbjörn, O Kousgård, M	Headache and mucus membrane irritation. An epidemiological study	249
Bervick, M Zagraniaki, R T Leaderer, B P Stolwijk, J A J	Respiratory illness in children exposed to unwanted combustion sources	255
Lets, R Quackenbush, J J Spengler, J D	Effects of choice of exposure index in NO ₂ epidemiological studies	261

2023379693

		10
HOUSING EPIDEMIOLOGY		267
Goldstein, I Hartel, D Andrews, L	Indoor exposure of asthmatics to nitrogen dioxide	269
Loewenstein, J C Bourdel, M C Maffiolo, G Krainik, P Wolmark, Y	Relation of environmental conditions to the health of the elderly in a long term care hospital: A longitudinal survey	275
Mage, D T	A possible relationship of sudden infant death syndrome to indoor air quality	281
Speizer, F E Ware, J Dockery, D Ferris Jr, B G	Lack of effect of gas stoves on longitudinal change in lung function in children ages 6-11 years	287
PASSIVE SMOKING AND HEALTH EFFECTS		295
Weber, A	Environmental tobacco smoke exposure: acute effects - acceptance levels - protective measures	297
Schmidt, P	Passive smoking as a real risk to health	303
Ferris Jr, B G Dockery, D W Ware, J H Berkey, C S Speizer, F E	Effects of passive smoking on children in the six-cities study	309
Hoffmann, D Brunnemann, K D Adams, J D Malley, M J	Indoor air pollution by tobacco smoke: Model studies on the uptake by nonsmokers	313
Hugod, C	Passive smoking - a source of indoor air pollution	319
PASSIVE SMOKING: CHARACTERIZATION AND COUNTERMEASURES		327
Sterling, T D	Effects of restricting and prohibiting smoking in office environments on reactions of office personnel to environmental health and stress factors	329
Matsushita, H Mori, T	Nitrogen dioxide and nitrosamine levels in indoor air and side-stream smoke of cigarette	335

2023379694

		11
Lehti, H	Ashtray	341
Vertio, H		
Ramström, L M	Smokers' and non-smokers' perception of passive smoking and certain control measures	345
Winnika, G	Patterns and determinants of reaction to tobacco smoke in an experimental exposure setting	351
Plischka, K		
Roscovanu, A		
Schlipkoeter, H W		

2023379695

RESPIRATORY ILLNESS IN CHILDREN EXPOSED TO
UNVENTED COMBUSTION SOURCES

Marianne Berwick, Rebecca T. Zagraniski*, Brian P. Leaderer**, and
Jan A. J. Stolwijk**

Dept. Epidemiology and Public Health, Yale University
School of Medicine, New Haven, CT 06510, USA

*New Jersey Department of Health, Trenton, NJ 08625, USA

**Dept. Epid. and Pub. Hlth., Yale Univ. School of Medicine and
J.B. Pierce Found. Lab., New Haven, CT 06510, USA

NOTICE
This material may be
protected by copyright
law (Title 17 U.S. Code)

Abstract

Using a staged design of air quality monitoring, we followed 174 families using unvented kerosene heaters and 173 families without heaters for a three-month period to evaluate the association between nitrogen dioxide (NO₂) exposure and acute respiratory illness rates. Environmental and health data were obtained through personal interview, bi-weekly telephone interviews, tax assessor records, and from two-week integrated NO₂ measurements in 303 residences. One hundred-twenty-one children under age 13 were followed in this study, 59 living in homes with kerosene heaters and 62 living in homes without. Initial analyses indicate that exposed children have significantly more days of acute respiratory illness than controls. Limitations are imposed by sample size and by possible selection bias.

Introduction

Unvented combustion in homes can lead to high ambient levels of several air contaminants with nitrogen dioxide (NO₂) being the most notable (1). While NO₂ has been implicated as a potentiator of lower respiratory infections in laboratory animals (2), the epidemiologic evidence for determining unhealthy levels in humans is inconclusive at this time. Melia *et al.* (3,4) and Florey *et al.* (5) have reported data that suggest that children between the ages of 5 and 11 living in homes with gas cooking stoves had higher levels of acute respiratory symptoms or disease than those living in homes with electric cooking stoves. The range of NO₂ exposures measured in these studies was from 8-634 ug/m³. The generalizability of these studies is limited by low

2023379696

response rates and an overrepresentation of lower socioeconomic status groups.

Keller *et al.* (6,7) found no difference in illness rates between volunteers who lived in homes using gas for cooking and those using electricity. The range of NO_2 exposures in their study was reported for a sample of homes only and was very low (22 ug/m^3), so that it was unlikely that any positive association could be found. The potential for recall bias limits the finding of Speizer *et al.* (8) that children living in homes with gas cooking stoves had higher respiratory illness rates before age two than children living in homes using electricity stoves. Dodge (9) reported that exposure to parental smoking and gas cooking was associated with higher respiratory symptom rates in Arizona schoolchildren. However, his sample is unrepresentative, suffered from low response rates, and no pollutant measures were made.

The investigation reported here was designed to determine whether exposure to air contaminants emitted by kerosene space heaters, particularly NO_2 , is associated with excess respiratory illness in children. We hypothesized that there was a positive correlation between NO_2 levels and acute respiratory illness rates among children. We identified a population with kerosene heaters where we could measure the household NO_2 exposures of children while accounting for many of the other potential risk factors for respiratory infections, such as parental smoking, presence of gas appliances, household size, school attendance, socioeconomic status, age, and previous history of respiratory infections.

Methods

Study Design and Population. To allow the most precise yet efficient estimation of individual exposures to pollutants, a staged design of air quality monitoring was employed in a cohort study. A cohort of adults who bought kerosene heaters was identified from lists obtained from local kerosene heater dealers in Connecticut. A control household was systematically chosen from the neighborhood of an exposed household. Neighborhood controls were selected to control ambient air quality and socioeconomic status. In each household an index woman, the oldest woman residing in the house, and an index child (if a child lived in the house), the child nearest in age to 5 but less than 13, were chosen to participate in the study. Households with no adult female present and households no longer using kerosene heaters were excluded from the study.

If subjects agreed to participate, an initial questionnaire was administered. Information was obtained about building characteristics, user heating patterns, and the health history and current respiratory symptomatology of the index adult and the index

2023379697

child (if present). Subjects were then followed up by telephone bi-weekly for 12 weeks during January-March 1983 to obtain respiratory symptoms for the female and the child (if present) and heater use patterns during the previous two weeks period. As described in a separate paper (10) air monitoring for NO_2 was conducted for at least one two-week period in 87.3 percent of the study households. The study population analyzed here consists of 121 children under age 13. Fifty-nine lived in homes with kerosene heaters; 62 lived in homes without. All children were Caucasian.

Definition of Variables. The independent variables used in these analyses included: (1) demographic factors: age, sex, socioeconomic status [SES, Hollingshead Index(11)]; (2) exposure parameters: number of minutes of gas cooking per day (total estimated oven and burner use), number of cigarettes normally smoked daily at home by all residents, school enrollment, type of cooking fuel, total household size (a proxy for density), average daily hours of kerosene heater use for each two-week period, one two-week average measurement of NO_2 in each residence, and (3) respiratory illness history. "Respiratory illness history" was a continuous variable derived by adding each serious respiratory disease reported in the initial questionnaire (i.e. ever had pneumonia) and the average number of chest colds per year (estimated by the mother).

We used the reported average hours of kerosene heater use during each two-week period as a proxy for NO_2 exposure. Average hours of heater use (by household) correlates fairly well with integrated average NO_2 measurements ($r = 0.70$, $p < 0.001$). The variable, average hours of heater use, was available for each child for each of 6 periods.

The dependent variable used in multivariate analysis, days of illness, was not normally distributed, so we dichotomized it as one or more days of illness and no days of illness and used linear logistic regression following the methods of Harrell (12). SAS 82.3 programs were used for nonparametric analyses and the linear logistic regression. For variables that were normally distributed (i.e. age, household size, etc.), we computed means, t-tests, and correlations using StatPac (13) on the IBMPC.

Results

Participation and Demographic Factors. The household participation rate among the exposed group was 77.9 percent and 80.7 percent among the unexposed. The loss to follow-up over the study period was 3.4 percent among the exposed group and 5.7 percent among the unexposed.

There were no statistically significant demographic differences

between the exposed and unexposed groups of children. The mean age of the children studied was 6.8 years, the mean household size was 4.2 persons per household, the mean index of SES was 43.4, and the mean index of history of respiratory illness was 2.7.

Exposure Factors. There was more gas cooking in the unexposed children's homes (46.5 minutes/day) when compared to the exposed children's (17.5 minutes/day), t -test=1.82, $p = 0.07$, two-tailed; however, since so few children's homes had gas stoves (8 exposed, 13 unexposed), there were not enough data for meaningful use in the present analysis. There was no statistically significant difference in the mean number of cigarettes smoked daily in children's homes (12.63 exposed, 12.74 unexposed). Average two-week integrated NO_2 samples were taken in 113 of the 121 children's homes in four places: outdoors, in the kitchen, in a living room, and in an adult's bedroom. The mean outdoor level of NO_2 for exposed households was 14.62 $\mu\text{g}/\text{m}^3$ (range 5-43 $\mu\text{g}/\text{m}^3$) and 12.70 $\mu\text{g}/\text{m}^3$ (range 0-26 $\mu\text{g}/\text{m}^3$) for unexposed households. The mean kitchen level of NO_2 in homes with kerosene heaters was 46.92 $\mu\text{g}/\text{m}^3$ (range 3-211 $\mu\text{g}/\text{m}^3$) and 14.07 $\mu\text{g}/\text{m}^3$ (range 0-80 $\mu\text{g}/\text{m}^3$) in homes without kerosene heaters. The mean living room level of NO_2 in children's homes with kerosene heaters was 46.84 $\mu\text{g}/\text{m}^3$ (range 3-154 $\mu\text{g}/\text{m}^3$) and 10.36 $\mu\text{g}/\text{m}^3$ (range 0-63 $\mu\text{g}/\text{m}^3$) in children's homes without kerosene heaters. The mean level of NO_2 found in bedrooms in exposed homes was 46.82 $\mu\text{g}/\text{m}^3$ (range 3-225 $\mu\text{g}/\text{m}^3$) and 10.4 $\mu\text{g}/\text{m}^3$ (range 0-66 $\mu\text{g}/\text{m}^3$) in bedrooms in unexposed homes. The overall average use of kerosene heaters was 7.7 hours per day (range 0-24 hours per day). NO_2 measurements in children's homes with kerosene heaters were on average 3-4 times as high as in homes without heaters.

Association between exposure and acute respiratory illness.

First, in order to determine whether kerosene heater exposure had an association with the days of illness, nonparametric statistical tests were applied to the data. Children exposed to kerosene heaters and children not exposed to heaters were ranked as to the total number of days sick over the 12 week follow-up period. A Wilcoxon rank sum test was performed using the t -approximation for the significance levels. Children living in homes with kerosene heaters had significantly more days of illness than children living in homes without kerosene heaters ($t=2.14$, $p < 0.05$).

Next, rank correlations were carried out between all independent variables and the dependent variable, days of illness. There was little association between average hours of heater use and number of days sick over the entire period (Spearman correlation coefficient, $r_s = 0.06$, $p = 0.09$). Age and history of respiratory illness were more strongly associated with days of illness ($r_s = 0.344$, $p < 0.01$, $r_s = -0.17$, $p < 0.05$, respectively).

Finally, linear logistic regression was used to determine which variables were significantly associated with one or more days of

2023379699

illness during each two-week period while adjusting for other measured potential risk factors. Average hours of heater use per day were significantly associated with days of illness ($p < 0.05$) while controlling for type of cooking fuel, cigarettes smoked per day, household size, sex, age, school enrollment, and history of respiratory illness. Age had a significant, inverse association with days of illness ($p < 0.05$). History of respiratory illness was positively associated ($p < 0.05$). SES was marginally associated ($p = 0.07$).

Discussion

This initial analysis suggests that young children with a history of respiratory infections are the most sensitive to the adverse health effects of NO_2 (or kerosene heater exposure). These results are consistent with previous studies that have shown that exposure to gas cooking has no effect on respiratory illness in women and school-age children (6,7), a borderline association with 5-11 year-olds (2,3,4) and an association with the history of respiratory illness in children under 2 years(7). The effects seem to be the most pronounced in young age groups. It should be emphasized that the results presented are preliminary.

These data are subject to many potential biases, some of which are: [1] recall bias in terms of reporting appliance use; [2] a limited ability to generalize from a convenience sample; [3] the publicity surrounding the safety of kerosene heaters; [4] all heater-owners had operated their heaters for at least one season prior to the study; as many as 34 potentially sensitive people were not eligible because they no longer used their heaters due to odor or hypersensitivity. A final limitation is the small sample size.

Further research should concentrate on studying the association between NO_2 exposure and younger-aged children.

Acknowledgements. The authors would like to gratefully acknowledge the constant support of Diane Goudreau, head interviewer, and the statistical advice of Ted Holford. This research was aided by a Grant-in-Aid of Research from Sigma Xi, and N.I.H. grants ES-07085 and ES-00354.

References

- (1) Leaderer, B.P. Air pollutant emissions from kerosene space heaters. Science, 1982, 218, 1113-1115.

2023379700

- (2) Ehrlich, R. Effect of air pollutants on respiratory infections. Arch. Env. Hlth. 1962, 6:638-642.
- (3) Melia, R.J.W., C. du V. Florey, D.G. Altman, and A.V. Swan. Association between gas cooking and respiratory disease in children. Brit. Med. J. 1977 (2):149-152.
- (4) Florey, C. du V., R.J.W. Melia, S. Chinn, B.D. Goldstein, A.G.F. Brooks, H.H. John, I.B. Craighead, and X. Webster. The relation between respiratory illness in primary schoolchildren and the use of gas for cooking III. Nitrogen dioxide, respiratory illness and lung function. Int. J. Epid. 1979, 8:347-353.
- (5) Melia, R.J.W., C. du V. Florey, R.W. Morris, B.D. Goldstein, H.H. John, D. Clark, I.B. Craighead, and J.C. Mackinlay. Childhood respiratory illness and the home environment II. Association between respiratory illness and nitrogen dioxide (NO_2), temperature and relative humidity. Int. J. Epid. 1982, 11:164-169.
- (6) Keller, M.D., R.R. Lanese, R.I. Mitchell, and R.W. Cote. Respiratory illness in households using gas and electricity for cooking. I. Survey of incidence. Env. Res. 19, 495-503 (1979).
- (7) Keller, M.D., R.R. Lanese, R.I. Mitchell, and R.W. Cote. Respiratory illness in households using gas and electricity for cooking. II. Symptoms and objective findings. Env. Res. 19, 504-515 (1979).
- (8) Speizer, F.E., B. Ferris, Jr., Y.M.M. Bishop, and J. Spengler. Respiratory disease rates and pulmonary function in children associated with NO_2 exposure. Am. Rev. Resp. Dis. 121, 1980, 3-10.
- (9) Dodge, R. The effects of indoor pollution on Arizona children. Arch. Env. Hlth. 1982, 37:151-155.
- (10) Leaderer, B.P., R.T. Zaganiski, N. Bervick, J.A.J. Stolwijk, and Q.S. Ma. Residential exposure to NO_2 , SO_2 , and HCHO associated with unvented kerosene space heaters, gas appliances and sidestream tobacco smoke. Proc. 3rd Intern. Conf. Indoor Air Quality and Climate, Stockholm 1984.
- (11) Hollingshead A.B. Two factor index of social position, New Haven, Ct: August B. Hollingshead Publications, 1957.
- (12) Harrell F. E. The logist procedure. SAS Supplemental Library User's Guide, 1980 Edition. SAS Institute, N.C. 1980.
- (13) Walonick, D.S. 1983. Statpac: Statistical analysis system for the IBMPC. Minneapolis, MI.

2023379701